

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

APPLICATION NO.: 10/787,292  
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APPELLANT: JOHN J. VAJO ET AL.  
GROUP ART UNIT: 1754  
CONFIRMATION NO.: 4952  
EXAMINER: WAYNE A. LANGEL  
TITLE: HYDROGEN STORAGE MATERIALS AND METHODS  
INCLUDING HYDRIDES AND HYDROXIDES  
ATTORNEY DOCKET: 8540R-000070 (GP-303955)

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**APPEAL BRIEF**

MS Appeal Brief - Patents  
Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

Dear Sir:

This is an appeal from the Office Action mailed January 18, 2007, finally rejecting Claims 1-9, 12-16, 18-22, 24, 25, 27-30, 70, 73-84, 87-90, 92-98, 102-118, 121-129, 131-138, 178, 179 and 181-194. A Notice of Appeal was mailed on April 13, 2007, appealing all of the rejected claims. The appeal brief is being filed as required under 37 C.F.R. § 41.37 within two months of the filing of the Notice of Appeal on April 13, 2007.

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I. Real Party In Interest

The real party in interest is General Motors Corporation. An assignment from the inventors to assignee, General Motors Corporation, was executed on February 19 and 23, 2004 and recorded with the U.S. Patent and Trademark Office at Reel/Frame No. 015025/0237.

II. Related Appeals, Interferences, And Judicial Proceedings

There are no other appeals, interferences, or judicial proceedings which will directly affect or be directly affected by or have a bearing on the Board's decision in this appeal.

III. Status Of Claims

Claims 1-199 are pending. Claims 1-9, 12-16, 18-22, 24, 25, 27-30, 70, 73-84, 87-90, 92-98, 102-118, 121-129, 131-138, 178, 179 and 181-194 are finally rejected. Claims 195-199 were withdrawn from consideration pursuant to a restriction requirement. Claims 10, 11, 17, 23, 26, 31-69, 71, 72, 85, 86, 91, 99-101, 119, 120, 130, 139-177 and 180 are objected to for being based upon rejected parent claims, however, contain allowable subject matter. The claims on appeal are all of the claims finally rejected, Claims 1-9, 12-16, 18-22, 24, 25, 27-30, 70, 73-84, 87-90, 92-98, 102-118, 121-129, 131-138, 178, 179 and 181-194.

IV. Status Of Amendments

Appellants filed an Amendment After Non-Final Rejection on November 21, 2006 amending Claims 57, 59, 69, 156, and 158. These amendments were entered.

V. Summary Of Claimed Subject Matter

The rejected claims include five independent claims (Claims 1, 82, 111, 178 and 187). Claims 1, 82 and 178 provide methods of producing hydrogen from a hydrogen storage material comprising a hydride and a hydroxide having one or more cations other than hydrogen. Claims 111 and 187 are directed to hydrogen storage compositions having a hydride and a hydroxide including one or more cations other than hydrogen.

In various aspects, the claimed methods of producing hydrogen are reversible, which is highly advantageous. Page 14, lines 14-21. The new hydrogen storage systems and methods of producing hydrogen (by conducting a reaction between a hydride and a hydroxide) desirably reduce overall enthalpy changes, thus reducing parasitic energy loss in a system and increasing gravimetric efficiency. Page 15, lines 7-23. These benefits are particularly advantageous for a mobile application, such as a fuel cell in a mobile unit. Page 1, lines 11-13; and Page 21, lines 5-10. Further, the claimed methods of producing hydrogen and the hydrogen storage compositions produce relatively high amounts of hydrogen. See for example, Page 17, lines 17-18; Page 18, lines 2, 6, 10, 14, 18; Page 19, lines 4, 11, 18; Page 20, line 1; Page 21, line 16; Page 22, lines 1, 11, 21; Page 26, lines 16, 19, 22; Page 29, lines 13, 18; Page 32, line 1; Page 33, line 12; Page 36, lines 18-19, and Figure 1.

Claims 1, 111, and 178

Independent Claims 1, 111, and 178 provide similar methods of producing hydrogen. Pages 4, lines 1-2, 18-19; Page 7, lines 1-2, 13-16; Page 30, lines 8-13; Page 37, lines 18-23; and Page 39, lines 3-14. Claims 1, 111, and 178 produce hydrogen to provide a hydrogen source to applications that consume hydrogen, for example fuel cells. Page 1, lines 11-13; and Page 21, lines 5-10. Claim 1 is representative of the methods recited in Claims 1, 111, and 178 and is

discussed in detail herein. The method of Claim 1 comprises conducting a reaction between a hydride composition and a hydroxide composition. Page 4, lines 2-3; Page 7, lines 3-6, 19-23; and Page 8, lines 1-5. The hydroxide composition has one or more cationic species other than hydrogen. Page 7, lines 5-6; and Page 8, lines 1-11. The reaction forms hydrogen and an oxide composition. Page 7, lines 6-7.

In various aspects, the claimed methods of producing hydrogen are reversible, which is highly advantageous. Page 14, lines 14-21. Moreover, the methods of Claims 1, 111, and 178 of producing hydrogen by conducting a reaction between a hydride and a hydroxide desirably reduce overall enthalpy changes, thus reducing parasitic energy loss in a system and increasing gravimetric efficiency. Page 15, lines 7-23. These benefits are particularly advantageous for a mobile application, such as a fuel cell in a mobile unit. Page 1, lines 11-13; and Page 21, lines 5-10. Claims 2-9, 12-16, 18-22, 24-25, 27-30, 70, and 73-81 depend upon Claim 1. Claims 112-118, 121-129, and 131-138 depend upon Claim 111. Claims 179, and 181-186 are dependent upon Claim 178.

#### Claim 82

Claim 82 is an independent claim that provides a method for releasing hydrogen from hydrogen storage materials. Page 4, lines 6-8. The hydrogen storage materials are used in a system that consumes hydrogen, such as a fuel cell. Page 1, lines 11-13; and Page 21, lines 5-10. Claim 82 comprises a method of mixing a first hydrogen storage material with a second hydrogen storage material. Page 4, lines 7-8. The first hydrogen storage material comprises a hydride composition represented by  $MI^xH_x$ . Page 4, lines 8-9; Page 7, lines 19-23. The second hydrogen storage material comprises a hydroxide composition represented by  $MI^y(OH)_y$ . Page

4, lines 10-11; Page 8, lines 1-5. MI and MII each represent a cationic species or a mixture of cationic species other than hydrogen, and where x and y represent average valence states of respectively MI and MII. Page 4, lines 11-13; and Page 8, line 6 bridging to Page 10, line 19. The method of Claim 82 further comprises conducting a reaction between the first storage material and the second storage material for a time and at a temperature sufficient to produce a reaction product comprising an oxide material and hydrogen. Page 4, lines 13-17. Claims 83-84, 87-90, 92-98, and 102-110 depend upon Claim 82.

#### Claim 109-110 and 187

Lastly, independent Claim 187 provides a mixture of a hydride and a hydroxide having cationic species other than hydrogen, where each one is characterized by promoting release of hydrogen from the other one in the presence of: a catalyst, elevated temperature, or both. Page 5, lines 6-9; Page 29, lines 19-22; Page 33, lines 15-20; Page 34, line 13 bridging to Page 35, line 16. Claims 188-194 depend upon Claim 187.

While Claims 109 and 110 are dependent upon independent method Claim 82, they share a common feature with Claim 187, namely the presence of a catalyst during the hydrogen release reaction. For example, Claim 109 is a representative claim and provides a method where the reaction is conducted in the presence of a catalyst. Page 34, line 18 bridging to Page 35, line 5.

#### Claims 28-30, 94-97 and 136-138

Claims 28-30, 94-97, and 136-138 further define over the cited art. Each of dependent Claims 28-30, 94-97, and 136-138 provide for specific combinations of hydride and hydroxide reactants in the specific reaction mechanisms. Page 8, line 19 bridging to Page 9, line 11; Page 12, lines 10-16; Page 13, lines 12-23; Page 16, lines 3-19. These reaction systems for hydrogen

storage provide particularly desirable overall enthalpy of reaction and relatively high theoretical yields. *Id.* Claims 28-30 depend upon Claim 1, Claims 94-97 upon Claim 82, and 136-138 upon Claim 111.

Claims 107 and 108

Dependent Claims 107 and 108, which depend upon Claim 82, further define over the cited art. Representative Claim 107 recites removing products, namely oxide and/or hydrogen products during the reaction from the starting materials. Page 34, lines 13-18; and Page 35, lines 6-10.

VI. Grounds Of Rejection To Be Reviewed On Appeal

Claims 1-9, 12-16, 18-22, 24, 25, 27-30, 70, 73-84, 87-90, 92-98, 102-118, 121-129, 131-138, 178, 179 and 181-194 stand rejected under 35 U.S.C. § 102(b) as anticipated by or, in the alternative, under 35 U.S.C. § 103(a) as obvious over Chen et al. (U.S. Pat. No. 6,471,936).



VII. Argument

- A. Chen fails to teach each limitation of Claims 1-9, 12-16, 18-22, 24, 25, 27-30, 70, 73-84, 87-90, 92-98, 102-118, 121-129, 131-138, 178, 179 and 181-194 and cannot anticipate or render the rejected claims obvious.

Claims 1-9, 12-16, 18-22, 24, 25, 27-30, 70, 73-84, 87-90, 92-98, 102-118, 121-129, 131-138, 178, 179 and 181-194 are patentable over Chen (U.S. Pat. No. 6,471,936), because the Chen reference fails to teach, either literally or inherently, the claimed methods of producing hydrogen or claimed hydrogen storage compositions having hydride and hydroxide compositions. The Chen reference provides methods of doping a carbon-based sorbent to enhance absorption and/or chemisorption of hydrogen on the carbon-based sorption materials. Col. 2, lines 35-37, 46-50; Col. 3, lines 8-12. The Chen reference pertains to forming hydrogen-sorption materials, not to hydrogen storage material systems having hydrides which react with hydroxides to produce hydrogen. Chen has no teaching or suggestion of a method of producing hydrogen by conducting a reaction between a hydride composition and a hydroxide composition.

First, the Chen reference does not anticipate Appellant's claims. "To anticipate a claim, a prior art reference must disclose every limitation of the claimed invention, either explicitly or inherently." *In re Schreiber*, 44 USPQ2d 1429, 1431 (Fed.Cir. 1997). The Chen reference fails to teach each and every limitation of the claimed invention. Specifically, the Chen reference does not teach or suggest a method of producing hydrogen from hydrogen storage materials by a reacting a hydride with a hydroxide, such as claimed in independent Claims 1, 82, and 178. Nor does the Chen reference provide a hydrogen storage composition, which comprises a hydride and a hydroxide. Similarly, Chen fails to specifically describe hydrogen storage based materials employing a hydride and a hydroxide to generate hydrogen, as found in Claims 111 and 187. While Chen provides methods of producing hydrogen via reversible sorption processes on a

doped carbon-based material, it does not teach producing hydrogen by conducting a reaction between a hydride and a hydroxide composition.

The Examiner points to the doping process in Chen that creates an alkali-metal carbon-based sorbent for anticipating and/or rendering the rejected claims obvious. However, nothing in the Chen reference teaches or suggests that hydrogen gas can, or more importantly will, be produced. Inherency may not be established by mere probabilities or possibilities. *Mehl/Biophile International Corp. v. Milgraum*, 52 USPQ.2d 1303, 1305 (Fed. Cir. 1999). The fact that a certain thing may result from a given set of circumstances is not sufficient to support a rejection under inherent anticipation. *Id.*, citing *In re Oelrich*, 666 F.2d 578, 581 (CCPA 1981). It should be noted that Chen provides no disclosure or suggestion of producing hydrogen in the calcination process that the Examiner relies upon. In fact, in Chen, hydrogen is intentionally present during calcination to provide a reducing atmosphere. One of skill in the art would appreciate that the presence of hydrogen for such a purpose would prevent potential reactants from forming products such as hydrogen and/or oxides by Le Chatelier's Principle. See for example, Appellants' Specification, Page 34, lines 3-18.

Thus, Chen cannot anticipate or render the claims obvious under the rubric of inherency, because Chen lacks a teaching of all the limitations of the claimed invention. A skilled artisan reviewing the Chen reference would have no guidance to arrive at the claimed invention, nonetheless assurance that the claimed invention would necessarily result from the processes of Chen. In fact, Chen teaches away from selecting conditions that could potentially arrive at the claimed invention. Chen describes reacting a carbon material with an alkali metal salt under high temperature treatment with either inert gases or a reducing environment (such as H<sub>2</sub> gas), to calcine the carbon material. Col. 3, lines 9-13. Along the same lines, Chen teaches avoiding

oxygen during the doping process, to avoid forming or using an oxide composition. Col. 3, lines 46-50 (“The alkali-doped carbon based materials are sensitive to oxygen or moisture. Exposure to oxygen during or after the calcination process greatly reduced the ability of the sorbent to take up hydrogen. It is therefore preferred to use a salt lacking oxygen in the calcination process”); Page 5, lines 24-28. Thus, Chen specifies avoiding oxygen during the calcination process, the same process that the Examiner relies upon; otherwise, the carbon-based sorption material will have a reduced ability for uptake of hydrogen (a primary object of Chen). Col. 3, lines 46-51; Col. 5, lines 25-27. Additionally, the teaching in Chen to avoid alkali metal salt containing oxygen also teaches away from the use of a hydroxide. Col. 3, lines 49-50; Col. 5, lines 27-28.

Chen lacks any description or suggestion to react a hydride composition with a hydroxide composition to form hydrogen. Chen only provides for a reaction between carbon with an alkali metal salt (preferably not containing oxygen), but does not provide an ancillary reaction between select specific alkali metal salts. It remains within the realm of pure speculation as to whether it would even be possible to create an oxide that reacts with a hydride to form hydrogen during the calcination/doping processes of Chen, notwithstanding the legal requirement that this must necessarily result every time from the process of Chen. While Chen recites various alkali metal salts that can be used to dope the carbon-based material, Chen teaches away from approaching the conditions necessary to approach the realm of the claimed invention. As such, there is simply no suggestion that mixtures or combinations of these alkali metals salts could, and more importantly should, be selected and used in an independent reaction to produce hydrogen. For these reasons, Claims 1-9, 12-16, 18-22, 24, 25, 27-30, 70, 73-84, 87-90, 92-98, 102-118, 121-129, 131-138, 178, 179 and 181-194 should be allowed.

1. Chen fails to describe generating hydrogen by a reaction with a hydride having the formula  $MI^xH_x$  and a hydroxide having the formula  $MII^y(OH)_y$ .

Independent Claim 82 is directed to a method for releasing hydrogen from hydrogen storage materials and further defines over the Chen reference. The respective hydrogen storage materials of Claim 82 comprise a hydride composition represented by  $MI^xH_x$  and a hydroxide composition represented by  $MII^y(OH)_y$ , where MI and MII each represent a cationic species or a mixture of cationic species other than hydrogen, and where x and y represent average valence states of respectively MI and MII. Claim 82 further recites conducting a reaction between the first and second storage materials for a time and temperature sufficient to produce a reaction product comprising an oxide material, as well as producing hydrogen.

The Chen reference has no teaching or suggestion of a hydrogen storage material formed of a hydride and a hydroxide as claimed in Claim 82 that generates both hydrogen and an oxide material. Chen merely states that the metal-doped carbon based material is formed by alkali metal salts such as carbonates, nitrates, hydroxides, halogenides, acetates, hydrides, nitrites or the like. Col. 5, lines 44-46. However, Chen provides no guidance to select any particular types of compounds within this broad description. In fact, the Chen reference teaches away from any such selection and combination of alkali metal salts, in stating that oxygen-containing alkali metal salts should be avoided, as discussed above. As such, the method of Claim 82 is neither described nor suggested by the Chen reference and should be allowed.

2. The reaction mechanisms recited in Claims 28-30, 94-97 and 136-138 are neither described nor suggested by the Chen reference.

Claims 28-30, 94-97, and 136-138 further define over the Chen reference, because Chen fails to disclose or suggest the specific combinations of reactants. For example, the particular combinations of hydride and hydroxide reactants, where LiH or NaH are selected as the hydride and LiOH is the hydroxide, for example, and the specific reaction mechanisms found in Claims 28-30, 94-97, and 136-138 are not provided or suggested by the teachings of Chen. These reactants and reactions were previously unknown as being capable of producing hydrogen, and are particularly advantageous for producing hydrogen at relatively high yields at industrially practicable temperature and pressure conditions. As such, Claims 28-30, 94-97, and 136-138 are neither anticipated by, nor rendered obvious in view of the Chen reference.

3. Chen fails anticipate or render obvious Claims 107 and 108, because Chen fails to teach removal of reaction products from hydride and hydroxide starting materials during a hydrogen production reaction.

Claims 107 and 108 are directed to methods of conducting a reaction, where the products, oxide and/or hydrogen are removed from the starting materials, which is not shown in Chen. In fact, Chen teaches away from such a proposition by teaching the use of a reducing atmosphere of hydrogen. Accordingly, Chen does not anticipate or render Claims 107 or 108 obvious.

4. Chen does not describe or suggest providing a catalyst or elevated temperature to promote release of hydrogen from hydride and hydroxide compositions, as claimed in Claims 109-110 and 187-194.

Independent Claim 187 is directed to a mixture of a hydride, a hydroxide, which promotes release of hydrogen in the presence of a catalyst, elevated temperature, or both. In dependent Claims 109 and 110, the reaction is conducted in the presence of a catalyst, which is further not described or suggested in the Chen reference. Chen fails to describe or suggest the particular hydrogen storage reactions provided in Appellant's application, but further, lacks any description or suggestion to use a catalyst to facilitate such reactions. As such, the Chen reference fails to anticipate or render obvious Claims 109-110, Claim 187 or its dependent Claims 188-194.

For all of these reasons, Appellants submit that Claims 1-9, 12-16, 18-22, 24, 25, 27-30, 70, 73-84, 87-90, 92-98, 102-118, 121-129, 131-138, 178, 179 and 181-194 are not anticipated or rendered obvious by the Chen reference and request that the rejection be REVERSED.

VIII. Conclusion

The present claims are patentable over the cited art.

As discussed above, the Examiner has not met the burden necessary under applicable law to demonstrate that the claims are anticipated, nor rendered obvious, over the cited art.

Appellants, therefore, respectfully ask this Honorable Board to reverse the final rejections of the claims on each ground and to indicate that all claims are allowable.

Dated: June 13, 2007

Respectfully submitted,

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## **CLAIMS APPENDIX**

### **Claims Involved in the Appeal of Application Serial No. 10/787,292**

1. A method of producing hydrogen comprising:  
conducting a reaction between a hydride composition and a hydroxide composition to form hydrogen and an oxide composition, wherein said hydroxide composition has one or more cationic species other than hydrogen.
2. The method according to claim 1 wherein said hydride composition has one or more cationic species other than hydrogen.
3. The method according to claim 2 wherein said oxide composition comprises at least one of said one or more cations other than hydrogen derived from either of said hydride or said hydroxide compositions, respectively.
4. The method according to claim 1 wherein said hydride composition is represented by the formula:  $MI^xH_x$ , where MI represents said one or more cationic species other than hydrogen and x represents an average valence state of MI.
5. The method according to claim 1 wherein said hydroxide composition is represented by the formula:  $MI^y(OH)_y$ , where MII represents said one or more cationic species other than hydrogen and y represents an average valence state of MII.



6. The method according to claim 1 wherein said hydroxide composition is represented by the formula:  $MII^y(OH)_y \cdot wH_2O$ , where MII represents said one or more cationic species other than hydrogen, y represents an average valence state of MII, and w represents a stoichiometric amount of hydrated water.

7. The method of claim 1 wherein said hydride composition is represented by  $MI^xH_x$  and said hydroxide composition is represented by  $MII^y(OH)_y$ , where MI and MII respectively represent one or more cationic species other than hydrogen, and x and y represent average valence states of MI and MII, respectively.

8. The method of claim 7 wherein MI and MII are different cationic species.

9. The method of claim 7 wherein MI and MII are the same cationic species.

10. The method of claim 7 wherein MI is a complex cationic species comprising two distinct cationic species.

11. The method of claim 7 wherein MII is a complex cationic species comprising two distinct cationic species.

12. The method of claim 7 wherein MI is selected from the group consisting of Al, As, B, Ba, Be, Ca, Cd, Ce, Cs, Cu, Eu, Fe, Ga, Gd, Ge, Hf, Hg, In, K, La, Li, Mg, Mn, Na, Nd, Ni, Pb, Pr, Rb, Sb, Sc, Se, Si, Sm, Sn, Sr, Th, Ti, Tl, V, W, Y, Yb, Zn, Zr, and mixtures thereof.

13. The method of claim 7 wherein MII is selected from the group consisting of  $\text{CH}_3$ ,  $\text{C}_2\text{H}_5$ ,  $\text{C}_3\text{H}_7$ , Al, As, B, Ba, Be, Ca, Cd, Ce, Cs, Cu, Eu, Fe, Ga, Gd, Ge, Hf, Hg, In, K, La, Li, Mg, Mn, Na, Nd, Ni, Pb, Pr, Rb, Sb, Sc, Se, Si, Sm, Sn, Sr, Th, Ti, Tl, V, W, Y, Yb, Zn, Zr, and mixtures thereof.

14. The method of claim 13 wherein MI and MII are each elements independently selected from the group consisting of Al, B, Ba, Be, Ca, Cs, K, Li, Mg, Na, Rb, Si, Sr, Ti, V and mixtures thereof.

15. The method of claim 14 wherein MI and MII are each elements independently selected from the group consisting of Al, B, Be, Ca, K, Li, Mg, Na, Sr, Ti, and mixtures thereof.

16. The method of claim 7 wherein said hydroxide composition further comprises:  $\text{MI}^y(\text{OH})_y \cdot w\text{H}_2\text{O}$ , where MII represents said one or more cationic species other than hydrogen,  $y$  represents an average valence state of MII, and  $w$  represents a stoichiometric amount of hydrated water.

17. The method of claim 16 wherein said oxide composition is a complex oxide.

18. The method of claim 1 wherein said hydride composition is represented by  $\text{MI}^x\text{H}_x$  and said hydroxide composition is represented by  $\text{MI}^y(\text{OH})_y \cdot w\text{H}_2\text{O}$ , where MII represents said

one or more cationic species other than hydrogen, y represents an average valence state of MII, and w represents a stoichiometric amount of hydrated water.

19. The method of claim 18 wherein MI is selected from the group consisting of Al, As, B, Ba, Be, Ca, Cd, Ce, Cs, Cu, Eu, Fe, Ga, Gd, Ge, Hf, Hg, In, K, La, Li, Mg, Mn, Na, Nd, Ni, Pb, Pr, Rb, Sb, Sc, Se, Si, Sm, Sn, Sr, Th, Ti, Tl, V, W, Y, Yb, Zn, Zr, and mixtures thereof.

20. The method of claim 19 wherein MII is selected from the group consisting of Al, As, B, Ba, Be, Ca, Cd, Ce, Cs, Cu, Eu, Fe, Ga, Gd, Ge, Hf, Hg, In, K, La, Li, Mg, Mn, Na, Nd, Ni, Pb, Pr, Rb, Sb, Sc, Se, Si, Sm, Sn, Sr, Th, Ti, Tl, V, W, Y, Yb, Zn, Zr, and mixtures thereof.

21. The method of claim 20 wherein MI and MII are each elements independently selected from the group consisting of Al, B, Ba, Be, Ca, Cs, K, Li, Mg, Na, Rb, Si, Sr, Ti, V and mixtures thereof.

22. The method of claim 21 wherein MI and MII are each elements independently selected from the group consisting of Al, B, Be, Ca, K, Li, Mg, Na, Sr, Ti, and mixtures thereof.

23. The method according to claim 1 wherein said hydroxide composition comprises an organic group.

24. The method according to claim 1 wherein said hydride composition is selected from the group consisting of: lithium hydride (LiH), sodium hydride (NaH), potassium hydride

(KH), beryllium hydride ( $\text{BeH}_2$ ), magnesium hydride ( $\text{MgH}_2$ ), calcium hydride ( $\text{CaH}_2$ ), strontium hydride ( $\text{SrH}_2$ ), titanium hydride ( $\text{TiH}_2$ ), aluminum hydride ( $\text{AlH}_3$ ), boron hydride ( $\text{BH}_3$ ), lithium borohydride ( $\text{LiBH}_4$ ), sodium borohydride ( $\text{NaBH}_4$ ), magnesium borohydride ( $\text{Mg}(\text{BH}_4)_2$ ), calcium borohydride ( $\text{Ca}(\text{BH}_4)_2$ ), lithium alanate ( $\text{LiAlH}_4$ ), sodium alanate ( $\text{NaAlH}_4$ ), magnesium alanate ( $\text{Mg}(\text{AlH}_4)_2$ ), calcium alanate ( $\text{Ca}(\text{AlH}_4)_2$ ), and mixtures thereof.

25. The method according to claim 1 wherein said hydroxide composition is selected from the group consisting of: lithium hydroxide ( $\text{LiOH}$ ), sodium hydroxide ( $\text{NaOH}$ ), potassium hydroxide ( $\text{KOH}$ ), beryllium hydroxide ( $\text{Be}(\text{OH})_2$ ), magnesium hydroxide ( $\text{Mg}(\text{OH})_2$ ), calcium hydroxide ( $\text{Ca}(\text{OH})_2$ ), strontium hydroxide ( $\text{Sr}(\text{OH})_2$ ), titanium hydroxide ( $\text{Ti}(\text{OH})_2$ ), aluminum hydroxide ( $\text{Al}(\text{OH})_3$ ), boron hydroxide ( $\text{B}(\text{OH})_3$ ) and mixtures thereof.

26. The method according to claim 1 wherein said hydroxide composition is selected from the group consisting of: hydrated lithium hydroxide ( $\text{LiOH} \cdot \text{H}_2\text{O}$ ), hydrated sodium hydroxide ( $\text{NaOH} \cdot \text{H}_2\text{O}$ ), hydrated potassium hydroxide ( $\text{KOH} \cdot \text{H}_2\text{O}$ ), hydrated barium hydroxide ( $\text{Ba}(\text{OH})_2 \cdot 3\text{H}_2\text{O}$ ), hydrated barium hydroxide ( $\text{Ba}(\text{OH})_2 \cdot \text{H}_2\text{O}$ ), hydrated lithium aluminum hydroxide ( $\text{LiAl}_2(\text{OH})_7 \cdot 2\text{H}_2\text{O}$ ), hydrated magnesium aluminum hydride ( $\text{Mg}_6\text{Al}_2(\text{OH})_{18} \cdot 4\text{H}_2\text{O}$ ), and mixtures thereof.

27. The method according to claim 1 wherein said hydride composition comprises  $\text{LiH}$  and said hydroxide composition comprises  $\text{LiOH}$ .

28. The method according to claim 27 wherein said reaction proceeds according to a reaction mechanism of  $\text{LiH} + \text{LiOH} \rightarrow \text{Li}_2\text{O} + \text{H}_2$ .

29. The method according to claim 1 wherein said hydride composition comprises NaH and said hydroxide composition comprises LiOH.

30. The method according to claim 29 wherein said reaction proceeds according to a reaction mechanism of  $\text{NaH} + \text{LiOH} \rightarrow \frac{1}{2} \text{Li}_2\text{O} + \frac{1}{2} \text{Na}_2\text{O} + \text{H}_2$ .

31. The method according to claim 1 wherein said hydride composition comprises  $\text{MgH}_2$  and said hydroxide composition comprises  $\text{Mg}(\text{OH})_2$ .

32. The method according to claim 31 wherein said reaction proceeds according to a reaction mechanism of  $\text{MgH}_2 + \text{Mg}(\text{OH})_2 \rightarrow \text{MgO} + 2 \text{H}_2$ .

33. The method according to claim 1 wherein said hydride composition comprises  $\text{AlH}_3$  and said hydroxide composition comprises  $\text{Al}(\text{OH})_3$ .

34. The method according to claim 33 wherein said reaction proceeds according to a reaction mechanism of  $\text{AlH}_3 + \text{Al}(\text{OH})_3 \rightarrow \text{Al}_2\text{O}_3 + 3\text{H}_2$ .

35. The method according to claim 1 wherein said hydride composition comprises  $\text{CaH}_2$  and said hydroxide composition comprises  $\text{Ca}(\text{OH})_2$ .

36. The method according to claim 35 wherein said reaction proceeds according to a reaction mechanism of  $\text{CaH}_2 + \text{Ca}(\text{OH})_2 \rightarrow \text{CaO} + 2 \text{H}_2$ .

37. The method according to claim 1 wherein said hydride composition comprises  $\text{SrH}_2$  and said hydroxide composition comprises  $\text{Sr}(\text{OH})_2$ .

38. The method according to claim 37 wherein said reaction proceeds according to a reaction mechanism of  $\text{SrH}_2 + \text{Sr}(\text{OH})_2 \rightarrow \text{SrO} + 2 \text{H}_2$ .

39. The method according to claim 1 wherein said hydride composition comprises  $\text{BH}_3$  and said hydroxide composition comprises  $\text{B}(\text{OH})_3$ .

40. The method according to claim 39 wherein said reaction proceeds according to a reaction mechanism of  $\text{BH}_3 + \text{B}(\text{OH})_3 \rightarrow \text{B}_2\text{O}_3 + 3 \text{H}_2$ .

41. The method according to claim 1 wherein said hydride composition comprises  $\text{BeH}_2$  and said hydroxide composition comprises  $\text{Be}(\text{OH})_2$ .

42. The method according to claim 41 wherein said reaction proceeds according to a reaction mechanism of  $\text{BeH}_2 + \text{Be}(\text{OH})_2 \rightarrow \text{BeO} + 2 \text{H}_2$ .

43. The method according to claim 1 where said hydride composition comprises  $\text{LiBH}_4$  and said hydroxide composition comprises  $\text{B(OH)}_3$ .

44. The method according to Claim 43 where said reaction proceeds according to a reaction mechanism of  $3\text{LiH} + \text{H}_3\text{BO}_3 \rightarrow \text{LiBO}_2 + \text{Li}_2\text{O} + 3\text{H}_2$ .

45. The method according to Claim 43 where said reaction proceeds according to a reaction mechanism of  $3\text{LiH} + \text{H}_3\text{BO}_3 \rightarrow \text{Li}_3\text{BO}_3 + 3\text{H}_2$ .

46. The method according to Claim 43 where said reaction proceeds according to a reaction mechanism of  $3\text{LiBH}_4 + 4\text{H}_3\text{BO}_3 \rightarrow \text{Li}_3\text{B}_7\text{O}_{12} + 12\text{H}_2$ .

47. The method according to claim 1 where said hydride composition comprises  $\text{LiBH}_4$  and said hydroxide composition comprises  $\text{LiOH}$ .

48. The method according to Claim 47 where said reaction proceeds according to a reaction mechanism of  $\text{LiBH}_4 + 4\text{LiOH} \rightarrow \text{LiBO}_2 + 2\text{Li}_2\text{O} + 4\text{H}_2$

49. The method according to claim 1 where said hydride composition comprises  $\text{NaBH}_4$  and said hydroxide composition comprises  $\text{Mg(OH)}_2$ .

50. The method according to Claim 49 where said reaction proceeds according to a reaction mechanism of  $\text{NaBH}_4 + 2 \text{Mg}(\text{OH})_2 \rightarrow \text{NaBO}_2 + 2\text{MgO} + 4\text{H}_2$

51. The method according to claim 1 where said hydride composition comprises  $\text{NaBH}_4$  and said hydroxide composition comprises  $\text{NaOH}$ .

52. The method according to Claim 51 where said reaction proceeds according to a reaction mechanism of  $\text{NaBH}_4 + 4\text{NaOH} \rightarrow \text{NaBO}_2 + 2\text{Na}_2\text{O} + 4\text{H}_2$ .

53. The method according to claim 1 where said hydride composition comprises  $\text{LiBH}_4$  and said hydroxide composition comprises  $\text{LiOH}$  and  $\text{LiOH} \cdot \text{H}_2\text{O}$ .

54. The method according to Claim 53 where said reaction proceeds according to a reaction mechanism of  $\text{LiBH}_4 + \text{LiOH} + \text{LiOH} \cdot \text{H}_2\text{O} \rightarrow \text{Li}_3\text{BO}_3 + 2 \text{Li}_2\text{O} + 4\text{H}_2$ .

55. The method according to Claim 53 where said reaction proceeds according to a reaction mechanism of  $2 \text{LiBH}_4 + \text{LiOH} + 2 \text{LiOH} \cdot \text{H}_2\text{O} \rightarrow \text{Li}_4\text{B}_2\text{O}_5 + \text{LiH} + 7 \text{H}_2$ .

56. The method according to claim 1 wherein said hydride composition comprises  $\text{MgH}_2$  and said hydroxide composition comprises  $\text{LiOH} \cdot \text{H}_2\text{O}$ .



57. The method according to claim 56 wherein said reaction proceeds according to a reaction mechanism of  $3 \text{ MgH}_2 + 2 \text{ LiOH} \cdot \text{H}_2\text{O} \rightarrow 3 \text{ MgO} + \text{Li}_2\text{O} + 6 \text{ H}_2$ .

58. The method according to claim 1 wherein said hydride composition comprises LiH and said hydroxide composition comprises  $\text{LiOH} \cdot \text{H}_2\text{O}$ .

59. The method according to claim 58 wherein said reaction proceeds according to a reaction mechanism of  $3 \text{ LiH} + \text{LiOH} \cdot \text{H}_2\text{O} \rightarrow 2 \text{ Li}_2\text{O} + 3 \text{ H}_2$ .

60. The method according to claim 1 wherein said hydride composition comprises NaH and said hydroxide composition comprises  $\text{LiOH} \cdot \text{H}_2\text{O}$ .

61. The method according to claim 60 wherein said reaction proceeds according to a reaction mechanism of  $6 \text{ NaH} + 2 \text{ LiOH} \cdot \text{H}_2\text{O} \rightarrow 3 \text{ Na}_2\text{O} + \text{Li}_2\text{O} + 6 \text{ H}_2$ .

62. The method according to claim 1 wherein said hydride composition comprises LiH and said hydroxide composition comprises  $\text{NaOH} \cdot \text{H}_2\text{O}$ .

63. The method according to claim 62 wherein said reaction proceeds according to a reaction mechanism of  $6 \text{ LiH} + 2 \text{ NaOH} \cdot \text{H}_2\text{O} \rightarrow 3 \text{ Li}_2\text{O} + \text{Na}_2\text{O} + 6 \text{ H}_2$ .

64. The method according to claim 1 wherein said hydride composition comprises NaH and said hydroxide composition comprises NaOH·H<sub>2</sub>O.

65. The method according to claim 64 wherein said reaction proceeds according to a reaction mechanism of  $3\text{NaH} + \text{NaOH}\cdot\text{H}_2\text{O} \rightarrow 2\text{Na}_2\text{O} + 3\text{H}_2$ .

66. The method according to claim 1 wherein said hydride composition comprises LiBH<sub>4</sub> and said hydroxide composition comprises LiOH·H<sub>2</sub>O.

67. The method according to claim 66 wherein said reaction proceeds according to a reaction mechanism of  $3\text{LiBH}_4 + 4\text{LiOH}\cdot\text{H}_2\text{O} \rightarrow 3\text{LiBO}_2 + 2\text{Li}_2\text{O} + 12\text{H}_2$ .

68. The method according to claim 1 wherein said hydride composition comprises NaBH<sub>4</sub> and said hydroxide composition comprises NaOH·H<sub>2</sub>O.

69. The method according to claim 68 wherein said reaction proceeds according to a reaction mechanism of  $3\text{NaBH}_4 + 3\text{NaBH}_4 + 4\text{NaOH}\cdot\text{H}_2\text{O} + 4\text{NaOH}\cdot\text{H}_2\text{O} \rightarrow 3\text{NaBO}_2 + 3\text{NaBO}_2 + 2\text{Na}_2\text{O} + 2\text{Na}_2\text{O} + 12\text{H}_2 + 12\text{H}_2$ .

70. The method according to claim 1 wherein said reaction is reversible to form a species of said hydride composition or said hydroxide composition.

71. The method according to claim 70 wherein said reversible reaction is conducted by exposing said oxide composition to hydrogen to form said species.

72. The method according to claim 71 wherein said reversible reaction regenerates said hydride composition and said hydroxide composition.

73. The method according to claim 1 wherein said reaction is conducted at an elevated temperature relative to ambient conditions.

74. The method according to claim 73 wherein said reaction is conducted at a temperature 40° C or greater.

75. The method according to claim 1 wherein said hydride composition and said hydroxide composition are in particle form and said reaction is a solid-state reaction.

76. The method according to claim 75 wherein said hydride composition and said hydroxide composition are reduced in particle size prior to said reaction.

77. The method according to claim 1 wherein before conducting said reaction, said hydride composition and said hydroxide composition are essentially homogeneously mixed together.

78. The method according to claim 1 wherein during said reaction, said oxide composition, said hydrogen, or both, are removed from said hydride composition and said hydroxide composition, as said reaction proceeds.

79. The method according to claim 1 wherein during said reaction said hydrogen is a removed as said reaction proceeds.

80. The method according to claim 1 wherein said reaction is conducted in the presence of a catalyst in contact with said hydride composition and said hydroxide composition.

81. The method according to claim 80 wherein said catalyst comprises a compound comprising an element selected from the group consisting of Ti, V, Cr, C, Fe, Mn, Ni, Nb, Pd, Si, Al, and mixtures thereof.

82. A method for releasing hydrogen from hydrogen storage materials comprising: mixing a first hydrogen storage material with a second hydrogen storage material, where said first hydrogen storage material comprises a hydride composition represented by  $MI^xH_x$  and said second hydrogen storage material comprises a hydroxide composition represented by  $MII^y(OH)_y$ , where MI and MII each represent a cationic species or a mixture of cationic species other than hydrogen, and where x and y represent average valence states of respectively MI and MII; and conducting a reaction between said first storage material with said second storage material for a time and at a temperature sufficient to produce a reaction product comprising an oxide material and hydrogen.

83. The method of claim 82 wherein MI and MII are different cationic species.
84. The method of claim 82 wherein MI and MII are the same cationic species.
85. The method of claim 82 wherein MI is a complex cationic species comprising two distinct cationic species.
86. The method of claim 82 wherein MII is a complex cationic species comprising two distinct cationic species.
87. The method of claim 82 wherein MI is selected from the group consisting of Al, As, B, Ba, Be, Ca, Cd, Ce, Cs, Cu, Eu, Fe, Ga, Gd, Ge, Hf, Hg, In, K, La, Li, Mg, Mn, Na, Nd, Ni, Pb, Pr, Rb, Sb, Sc, Se, Si, Sm, Sn, Sr, Th, Ti, Tl, V, W, Y, Yb, Zn, Zr, and mixtures thereof.
88. The method of claim 82 wherein MII is selected from the group consisting of CH<sub>3</sub>, C<sub>2</sub>H<sub>5</sub>, C<sub>3</sub>H<sub>7</sub>, Al, As, B, Ba, Be, Ca, Cd, Ce, Cs, Cu, Eu, Fe, Ga, Gd, Ge, Hf, Hg, In, K, La, Li, Mg, Mn, Na, Nd, Ni, Pb, Pr, Rb, Sb, Sc, Se, Si, Sm, Sn, Sr, Th, Ti, Tl, V, W, Y, Yb, Zn, Zr, and mixtures thereof.
89. The method of claim 88 wherein MI and MII are each elements independently selected from the group consisting of Al, B, Ba, Be, Ca, Cs, K, Li, Mg, Na, Rb, Si, Sr, Ti, V and mixtures thereof.

90. The method of claim 89 wherein MI and MII are each elements independently selected from the group consisting of Al, B, Be, Ca, K, Li, Mg, Na, Sr, Ti, and mixtures thereof.

91. The method according to claim 82 wherein said hydroxide composition comprises an organic group.

92. The method according to claim 82 wherein said hydride composition is selected from the group consisting of: lithium hydride (LiH), sodium hydride (NaH), potassium hydride (KH), beryllium hydride ( $\text{BeH}_2$ ), magnesium hydride ( $\text{MgH}_2$ ), calcium hydride ( $\text{CaH}_2$ ), strontium hydride ( $\text{SrH}_2$ ), titanium hydride ( $\text{TiH}_2$ ), aluminum hydride ( $\text{AlH}_3$ ), boron hydride ( $\text{BH}_3$ ), lithium borohydride ( $\text{LiBH}_4$ ), sodium borohydride ( $\text{NaBH}_4$ ), magnesium borohydride ( $\text{Mg}(\text{BH}_4)_2$ ), calcium borohydride ( $\text{Ca}(\text{BH}_4)_2$ ), lithium alanate ( $\text{LiAlH}_4$ ), sodium alanate ( $\text{NaAlH}_4$ ), magnesium alanate ( $\text{Mg}(\text{AlH}_4)_2$ ), calcium alanate ( $\text{Ca}(\text{AlH}_4)_2$ ), and mixtures thereof.

93. The method according to claim 82 wherein said hydroxide composition is selected from the group consisting of: lithium hydroxide (LiOH), sodium hydroxide (NaOH), potassium hydroxide (KOH), beryllium hydroxide ( $\text{Be}(\text{OH})_2$ ), magnesium hydroxide ( $\text{Mg}(\text{OH})_2$ ), calcium hydroxide ( $\text{Ca}(\text{OH})_2$ ), strontium hydroxide ( $\text{Sr}(\text{OH})_2$ ), titanium hydroxide ( $\text{Ti}(\text{OH})_2$ ), aluminum hydroxide ( $\text{Al}(\text{OH})_3$ ), boron hydroxide ( $\text{B}(\text{OH})_3$ ) and mixtures thereof.

94. The method according to claim 82 wherein said hydride composition comprises LiH and said hydroxide composition comprises LiOH.

95. The method according to claim 94 wherein said reaction proceeds according to a reaction mechanism of  $\text{LiH} + \text{LiOH} \rightarrow \text{Li}_2\text{O} + \text{H}_2$ .

96. The method according to claim 82 wherein said hydride composition comprises NaH and said hydroxide composition comprises LiOH.

97. The method according to claim 96 wherein said reaction proceeds according to a reaction mechanism of  $\text{NaH} + \text{LiOH} \rightarrow \frac{1}{2} \text{Li}_2\text{O} + \frac{1}{2} \text{Na}_2\text{O} + \text{H}_2$ .

98. The method according to claim 82 wherein said second hydrogen storage material further comprises a second hydroxide composition represented by  $\text{MII}^y(\text{OH})_y \cdot w\text{H}_2\text{O}$ , where MII represents said one or more cationic species other than hydrogen, y represents an average valence state of MII, and w represents a stoichiometric amount of hydrated water.

99. The method according to claim 98 wherein said hydroxide composition is selected from the group consisting of: hydrated lithium hydroxide ( $\text{LiOH} \cdot \text{H}_2\text{O}$ ), hydrated sodium hydroxide ( $\text{NaOH} \cdot \text{H}_2\text{O}$ ), hydrated potassium hydroxide ( $\text{KOH} \cdot \text{H}_2\text{O}$ ), hydrated barium hydroxide ( $\text{Ba}(\text{OH})_2 \cdot 3\text{H}_2\text{O}$ ), hydrated barium hydroxide ( $\text{Ba}(\text{OH})_2 \cdot \text{H}_2\text{O}$ ), hydrated lithium aluminum hydroxide ( $\text{LiAl}_2(\text{OH})_7 \cdot 2\text{H}_2\text{O}$ ), hydrated magnesium aluminum hydride ( $\text{Mg}_6\text{Al}_2(\text{OH})_{18} \cdot 4\text{H}_2\text{O}$ ), and mixtures thereof.

100. The method according to claim 82 wherein said reaction is reversed by exposing said oxide material to hydrogen to form a regenerated first storage material comprising a hydride and a regenerated second storage material comprising a hydroxide.

101. The method according to claim 100 wherein said hydride of said regenerated first storage material and said hydroxide of said regenerated second storage material are the same species as said first and said second starting materials, comprising said hydride and said hydroxide, respectively.

102. The method according to claim 82 wherein said reaction is conducted at an elevated temperature relative to ambient conditions.

103. The method according to claim 102 wherein said reaction is conducted at a temperature of 40° C or greater.

104. The method according to claim 82 wherein said first starting material and said second starting material are in particle form and said reaction is a solid state reaction.

105. The method according to claim 104 wherein said first starting material and said second starting material are reduced in particle size prior to said reaction.



106. The method according to claim 82 wherein before conducting said reaction, said first starting material and said second starting material are essentially homogeneously mixed together.

107. The method according to claim 82 wherein during said reaction, said oxide, said hydrogen, or both, are removed from said first starting material and said second starting material, as said reaction proceeds.

108. The method according to claim 82 wherein during said reaction said hydrogen is a removed from said first and said second starting materials as said reaction proceeds.

109. The method according to claim 82 wherein said reaction is conducted in the presence of a catalyst in contact with said first starting material and said second starting material.

110. The method according to claim 109 wherein said catalyst comprises a compound comprising an element selected from the group consisting of Ti, V, Cr, C, Fe, Mn, Ni, Nb, Pd, Si, Al, and mixtures thereof.

111. A hydrogen storage composition having a hydrogenated state and a dehydrogenated state:

(a) in said hydrogenated state, said composition comprises a hydride and a hydroxide having one or more cationic species other than hydrogen; and

(b) in said dehydrogenated state, said composition comprises an oxide.

112. The composition of claim 111 wherein said hydride is represented by the formula  $MI^xH_x$ , where MI represents one or more cationic species other than hydrogen, and x is an average valence state of MI.

113. The composition of claim 111 wherein said hydroxide is represented by the formula  $MII^y(OH)_y$ , where MII represents one or more cationic species other than hydrogen, and y is an average valence state of MII.

114. The method of claim 111 wherein said hydroxide is represented by the formula  $MII^y(OH)_y \cdot wH_2O$ , where MII represents said one or more cationic species other than hydrogen, y represents an average valence state of MII, and w represents a stoichiometric amount of hydrated water.

115. The composition of claim 111 wherein said hydroxide comprises a first hydroxide having the formula  $MII^y(OH)_y$  and a second hydroxide compound having the formula ,  $MII^y(OH)_y \cdot wH_2O$ , where MII represents said one or more cationic species other than hydrogen, y represents an average valence state of MII, and w represents a stoichiometric amount of hydrated water.

116. The method of claim 115 wherein said oxide comprises a complex higher-order oxide.

117. The composition of claim 111 wherein said hydride is represented by  $MI^xH_x$  and said hydroxide is represented by  $MI^y(OH)_y$ , where MI and MII respectively represent one or more cationic species other than hydrogen, and x and y represent average valence states of MI and MII, respectively.

118. The composition of claim 117 wherein MI and MII are different cationic species.

119. The composition of claim 117 wherein MI is a complex cationic species comprising two distinct cationic species.

120. The composition of claim 117 wherein MII is a complex cationic species comprising two distinct cationic species.

121. The composition of claim 117 wherein MI is selected from the group consisting of Al, As, B, Ba, Be, Ca, Cd, Ce, Cs, Cu, Eu, Fe, Ga, Gd, Ge, Hf, Hg, In, K, La, Li, Mg, Mn, Na, Nd, Ni, Pb, Pr, Rb, Sb, Sc, Se, Si, Sm, Sn, Sr, Th, Ti, Tl, V, W, Y, Yb, Zn, Zr, and mixtures thereof.

122. The composition of claim 117 wherein MII is selected from the group consisting of  $CH_3$ ,  $C_2H_5$ ,  $C_3H_7$ , Al, As, B, Ba, Be, Ca, Cd, Ce, Cs, Cu, Eu, Fe, Ga, Gd, Ge, Hf, Hg, In, K, La, Li, Mg, Mn, Na, Nd, Ni, Pb, Pr, Rb, Sb, Sc, Se, Si, Sm, Sn, Sr, Th, Ti, Tl, V, W, Y, Yb, Zn, Zr, and mixtures thereof.

123. The composition of claim 122 wherein MI and MII are each elements independently selected from the group consisting of Al, B, Ba, Be, Ca, Cs, K, Li, Mg, Na, Rb, Si, Sr, Ti, V and mixtures thereof.

124. The composition of claim 123 wherein MI and MII are each elements independently selected from the group consisting of Al, B, Be, Ca, K, Li, Mg, Na, Sr, Ti, and mixtures thereof.

125. The composition of claim 111 wherein said hydride is represented by  $MI^xH_x$  and said hydroxide is represented by  $MII^y(OH)_y \cdot wH_2O$ , where MI and MII respectively represent one or more cationic species other than hydrogen, x and y represent average valence states of MI and MII, respectively and w represents a stoichiometric amount of hydrated water.

126. The method of claim 125 wherein MI is selected from the group consisting of Al, As, B, Ba, Be, Ca, Cd, Ce, Cs, Cu, Eu, Fe, Ga, Gd, Ge, Hf, Hg, In, K, La, Li, Mg, Mn, Na, Nd, Ni, Pb, Pr, Rb, Sb, Sc, Se, Si, Sm, Sn, Sr, Th, Ti, Tl, V, W, Y, Yb, Zn, Zr, and mixtures thereof.

127. The method of claim 126 wherein MII is selected from the group consisting of Al, As, B, Ba, Be, Ca, Cd, Ce, Cs, Cu, Eu, Fe, Ga, Gd, Ge, Hf, Hg, In, K, La, Li, Mg, Mn, Na, Nd, Ni, Pb, Pr, Rb, Sb, Sc, Se, Si, Sm, Sn, Sr, Th, Ti, Tl, V, W, Y, Yb, Zn, Zr, and mixtures thereof.

128. The method of claim 127 wherein MI and MII are each elements independently selected from the group consisting of Al, B, Ba, Be, Ca, Cs, K, Li, Mg, Na, Rb, Si, Sr, Ti, V and mixtures thereof.

129. The method of claim 128 wherein MI and MII are each elements independently selected from the group consisting of Al, B, Be, Ca, K, Li, Mg, Na, Sr, Ti, and mixtures thereof.

130. The composition of claim 111 wherein said hydroxide comprises an organic group.

131. The composition of claim 111 wherein said hydride is selected from the group consisting of: lithium hydride (LiH), sodium hydride (NaH), potassium hydride (KH), beryllium hydride ( $\text{BeH}_2$ ), magnesium hydride ( $\text{MgH}_2$ ), calcium hydride ( $\text{CaH}_2$ ), strontium hydride ( $\text{SrH}_2$ ), titanium hydride ( $\text{TiH}_2$ ), aluminum hydride ( $\text{AlH}_3$ ), boron hydride ( $\text{BH}_3$ ), lithium borohydride ( $\text{LiBH}_4$ ), sodium borohydride ( $\text{NaBH}_4$ ), magnesium borohydride ( $\text{Mg}(\text{BH}_4)_2$ ), calcium borohydride ( $\text{Ca}(\text{BH}_4)_2$ ), lithium alanate ( $\text{LiAlH}_4$ ), sodium alanate ( $\text{NaAlH}_4$ ), magnesium alanate ( $\text{Mg}(\text{AlH}_4)_2$ ), calcium alanate ( $\text{Ca}(\text{AlH}_4)_2$ ), and mixtures thereof.

132. The composition of claim 111 wherein said hydroxide is selected from the group consisting of: lithium hydroxide (LiOH), sodium hydroxide (NaOH), potassium hydroxide (KOH), beryllium hydroxide ( $\text{Be}(\text{OH})_2$ ), magnesium hydroxide ( $\text{Mg}(\text{OH})_2$ ), calcium hydroxide ( $\text{Ca}(\text{OH})_2$ ), strontium hydroxide ( $\text{Sr}(\text{OH})_2$ ), titanium hydroxide ( $\text{Ti}(\text{OH})_2$ ), aluminum hydroxide ( $\text{Al}(\text{OH})_3$ ), boron hydroxide ( $\text{B}(\text{OH})_3$ ) and mixtures thereof.

133. The composition of claim 111 wherein said hydride comprises LiH.

134. The composition of claim 111 wherein said hydroxide comprises LiOH.

135. The composition of claim 111 wherein said hydride composition comprises LiH and said hydroxide composition comprises LiOH.

136. The composition of claim 135 wherein said reaction proceeds according to a reaction mechanism of  $\text{LiH} + \text{LiOH} \rightarrow \text{Li}_2\text{O} + \text{H}_2$ .

137. The composition of claim 111 wherein said hydride composition comprises NaH and said hydroxide composition comprises LiOH.

138. The composition of claim 137 wherein said reaction proceeds according to a reaction mechanism of  $\text{NaH} + \text{LiOH} \rightarrow \frac{1}{2} \text{Li}_2\text{O} + \frac{1}{2} \text{Na}_2\text{O} + \text{H}_2$ .

139. The method according to claim 111 wherein said hydride composition comprises  $\text{MgH}_2$  and said hydroxide composition comprises  $\text{Mg}(\text{OH})_2$ .

140. The method according to claim 139 wherein said reaction proceeds according to a reaction mechanism of  $\text{MgH}_2 + \text{Mg}(\text{OH})_2 \rightarrow \text{MgO} + 2 \text{H}_2$ .

141. The method according to claim 111 wherein said hydride composition comprises  $\text{AlH}_3$  and said hydroxide composition comprises  $\text{Al}(\text{OH})_3$ .

142. The method according to claim 141 wherein said reaction proceeds according to a reaction mechanism of  $\text{AlH}_3 + \text{Al}(\text{OH})_3 \rightarrow \text{Al}_2\text{O}_3 + 3\text{H}_2$ .

143. The method according to claim 111 wherein said hydride composition comprises  $\text{CaH}_2$  and said hydroxide composition comprises  $\text{Ca}(\text{OH})_2$ .

144. The method according to claim 143 wherein said reaction proceeds according to a reaction mechanism of  $\text{CaH}_2 + \text{Ca}(\text{OH})_2 \rightarrow \text{CaO} + 2\text{H}_2$ .

145. The method according to claim 111 wherein said hydride composition comprises  $\text{SrH}_2$  and said hydroxide composition comprises  $\text{Sr}(\text{OH})_2$ .

146. The method according to claim 145 wherein said reaction proceeds according to a reaction mechanism of  $\text{SrH}_2 + \text{Sr}(\text{OH})_2 \rightarrow \text{SrO} + 2\text{H}_2$ .

147. The method according to claim 111 wherein said hydride composition comprises  $\text{BH}_3$  and said hydroxide composition comprises  $\text{B}(\text{OH})_3$ .

148. The method according to claim 147 wherein said reaction proceeds according to a reaction mechanism of  $\text{BH}_3 + \text{B}(\text{OH})_3 \rightarrow \text{B}_2\text{O}_3 + 3\text{H}_2$ .

149. The method according to claim 111 wherein said hydride composition comprises  $\text{BeH}_2$  and said hydroxide composition comprises  $\text{Be}(\text{OH})_2$ .

150. The method according to claim 149 wherein said reaction proceeds according to a reaction mechanism of  $\text{BeH}_2 + \text{Be}(\text{OH})_2 \rightarrow \text{BeO} + 2 \text{H}_2$ .

151. The method according to claim 111 where said hydride composition comprises  $\text{LiBH}_4$  and said hydroxide comprises  $\text{B}(\text{OH})_3$ .

152. The method according to claim 151 where said reaction proceeds according to a reaction mechanism of  $3\text{LiH} + \text{H}_3\text{BO}_3 \rightarrow \text{LiBO}_2 + \text{Li}_2\text{O} + 3\text{H}_2$ .

153. The method according to claim 151 where said reaction proceeds according to a reaction mechanism of  $3\text{LiH} + \text{H}_3\text{BO}_3 \rightarrow \text{Li}_3\text{BO}_3 + 3\text{H}_2$ .

154. The method according to claim 151 where said reaction proceeds according to a reaction mechanism of  $3 \text{LiBH}_4 + 4 \text{H}_3\text{BO}_3 \rightarrow \text{Li}_3\text{B}_7\text{O}_{12} + 12 \text{H}_2$ .

155. The method according to claim 111 where said hydride composition comprises  $\text{LiBH}_4$  and said hydroxide comprises  $\text{LiOH}$ .



156. The method according to claim 155 where said reaction proceeds according to a reaction mechanism of  $\text{LiBH}_4 + 4 \text{LiOH} \rightarrow \text{LiBO}_2 + 2 \text{Li}_2\text{O} + 4\text{H}_2$ .

157. The method according to claim 111 where said hydride composition comprises  $\text{NaBH}_4$  and said hydroxide comprises  $\text{Mg}(\text{OH})_2$ .

158. The method according to claim 157 where said reaction proceeds according to a reaction mechanism of  $\text{NaBH}_4 + 2 \text{Mg}(\text{OH})_2 \rightarrow \text{NaBO}_2 + 2\text{MgO} + 4\text{H}_2$ .

159. The method according to claim 111 where said hydride composition comprises  $\text{NaBH}_4$  and said hydroxide comprises  $\text{NaOH}$ .

160. The method according to claim 159 where said reaction proceeds according to a reaction mechanism of  $\text{NaBH}_4 + 4 \text{NaOH} \rightarrow \text{NaBO}_2 + 2 \text{Na}_2\text{O} + 4 \text{H}_2$ .

161. The method according to claim 111 where said hydride composition comprises  $\text{LiBH}_4$  and said hydroxide composition comprises  $\text{LiOH}$  and  $\text{LiOH} \cdot \text{H}_2\text{O}$ .

162. The method according to claim 161 where said reaction proceeds according to a reaction mechanism of  $\text{LiBH}_4 + \text{LiOH} + \text{LiOH} \cdot \text{H}_2\text{O} \rightarrow \text{Li}_3\text{BO}_3 + 2 \text{Li}_2\text{O} + 4\text{H}_2$ .

163. The method according to claim 161 where said reaction proceeds according to a reaction mechanism of  $2 \text{LiBH}_4 + \text{LiOH} + 2 \text{LiOH} \cdot \text{H}_2\text{O} \rightarrow \text{Li}_4\text{B}_2\text{O}_5 + \text{LiH} + 7 \text{H}_2$ .

164. The method according to claim 111 wherein said hydride composition comprises  $\text{MgH}_2$  and said hydroxide composition comprises  $\text{LiOH}\cdot\text{H}_2\text{O}$ .

165. The method according to claim 164 wherein said reaction proceeds according to a reaction mechanism of  $3\text{MgH}_2 + 2\text{LiOH}\cdot\text{H}_2\text{O} \rightarrow 3\text{MgO} + \text{Li}_2\text{O} + 6\text{H}_2$ .

166. The method according to claim 111 wherein said hydride composition comprises  $\text{LiH}$  and said hydroxide composition comprises  $\text{LiOH}\cdot\text{H}_2\text{O}$ .

167. The method according to claim 166 wherein said reaction proceeds according to a reaction mechanism of  $3\text{LiH} + \text{LiOH}\cdot\text{H}_2\text{O} \rightarrow 2\text{Li}_2\text{O} + 3\text{H}_2$ .

168. The method according to claim 111 wherein said hydride composition comprises  $\text{NaH}$  and said hydroxide composition comprises  $\text{LiOH}\cdot\text{H}_2\text{O}$ .

169. The method according to claim 168 wherein said reaction proceeds according to a reaction mechanism of  $6\text{NaH} + 2\text{LiOH}\cdot\text{H}_2\text{O} \rightarrow 3\text{Na}_2\text{O} + \text{Li}_2\text{O} + 6\text{H}_2$ .

170. The method according to claim 111 wherein said hydride composition comprises  $\text{LiH}$  and said hydroxide composition comprises  $\text{NaOH}\cdot\text{H}_2\text{O}$ .

171. The method according to claim 170 wherein said reaction proceeds according to a reaction mechanism of  $6\text{LiH} + 2\text{NaOH}\cdot\text{H}_2\text{O} \rightarrow 3\text{Li}_2\text{O} + \text{Na}_2\text{O} + 6\text{H}_2$ .

172. The method according to claim 111 wherein said hydride composition comprises NaH and said hydroxide composition comprises  $\text{NaOH}\cdot\text{H}_2\text{O}$ .

173. The method according to claim 172 wherein said reaction proceeds according to a reaction mechanism of  $3\text{NaH} + \text{NaOH}\cdot\text{H}_2\text{O} \rightarrow 2\text{Na}_2\text{O} + 3\text{H}_2$ .

174. The method according to claim 111 wherein said hydride composition comprises  $\text{LiBH}_4$  and said hydroxide composition comprises  $\text{LiOH}\cdot\text{H}_2\text{O}$ .

175. The method according to claim 174 wherein said reaction proceeds according to a reaction mechanism of  $3\text{LiBH}_4 + 4\text{LiOH}\cdot\text{H}_2\text{O} \rightarrow 3\text{LiBO}_2 + 2\text{Li}_2\text{O} + 12\text{H}_2$ .

176. The method according to claim 111 wherein said hydride composition comprises  $\text{NaBH}_4$  and said hydroxide composition comprises  $\text{NaOH}\cdot\text{H}_2\text{O}$ .

177. The method according to claim 176 wherein said reaction proceeds according to a reaction mechanism of  $3\text{NaBH}_4 + 4\text{NaOH}\cdot\text{H}_2\text{O} \rightarrow 3\text{NaBO}_2 + 2\text{Na}_2\text{O} + 12\text{H}_2$ .

178. A method of producing a source of hydrogen gas comprising:  
liberating hydrogen from a solid hydrogenated starting material composition comprising a hydride and a hydroxide, by reacting said hydride and said hydroxide in a solid state reaction to produce a dehydrogenated reaction product and hydrogen gas.
179. The method according to claim 178 wherein said hydride and said hydroxide each have one or more cationic species other than hydrogen.
180. The method according to claim 178 further comprising regenerating said hydrogenated starting material composition by exposing said dehydrogenated product to hydrogen gas.
181. The method of claim 178 wherein said dehydrogenated product comprises an oxide.
182. The method of claim 178 wherein said regenerating is conducted at an elevated temperature relative to ambient conditions.
183. The method of claim 182 wherein said liberating of hydrogen is conducted at an elevated temperature greater than about 40°C.

184. The method of claim 178 wherein said liberating is conducted by removing said hydrogen gas as said reacting proceeds.

185. The method of claim 178 wherein said liberating is conducted in the presence of a catalyst in contact with said starting material composition.

186. The method according to claim 185 wherein said catalyst comprises a compound comprising an element selected from the group consisting of Ti, V, Cr, C, Fe, Mn, Ni, Nb, Pd, Si, Al, and mixtures thereof.

187. A mixture of a hydride and a hydroxide having cationic species other than hydrogen, each one characterized by promoting release of hydrogen from the other one in the presence of: a catalyst, elevated temperature, or both.

188. The mixture of claim 187 further characterized in that the release of hydrogen results in formation of an oxide.

189. The mixture of claim 187 wherein said hydride is represented by the formula  $MI^xH_x$ , where MI represents one or more cationic species other than hydrogen, and x is an average valence state of MI.

190. The mixture of claim 187 wherein said hydroxide is represented by the formula  $MII^y(OH)_y$ , where MII represents one or more cationic species other than hydrogen, and y is an average valence state of MII.

191. The method of claim 187 wherein said hydroxide is represented by the formula  $MII^y(OH)_y \cdot wH_2O$ , where MII represents said one or more cationic species other than hydrogen, y represents an average valence state of MII, and w represents a stoichiometric amount of hydrated water.

192. The composition of claim 187 wherein said hydroxide comprises a first hydroxide compound having the formula  $MII^y(OH)_y$  and a second hydroxide compound having the formula  $MII^y(OH)_y \cdot wH_2O$ , where MII represents said one or more cationic species other than hydrogen, y represents an average valence state of MII, and w represents a stoichiometric amount of hydrated water.

193. The composition of claim 187 wherein said hydride is represented by  $MI^xH_x$  and said hydroxide is represented by  $MII^y(OH)_y \cdot wH_2O$ , where MI and MII respectively represent one or more cationic species other than hydrogen, x and y represent average valence states of MI and MII, respectively, and w represents a stoichiometric amount of hydrated water.

194. The mixture of claim 187 wherein said hydride is represented by  $MI^xH_x$  and said hydroxide is represented by  $MII^y(OH)_y$ , where MI and MII respectively represent said one or

more cationic species other than hydrogen, and  $x$  and  $y$  represent average valence states of MI and MII, respectively.

195. (withdrawn) A power device comprising:

a fuel cell that uses hydrogen as fuel;

a storage unit containing a hydrogen storage material

having a hydrogenated state and a dehydrogenated state, wherein said storage material releases hydrogen used as fuel in said fuel cell, wherein said hydrogenated state of said storage material comprises a hydroxide having a cationic species other than hydrogen and a hydride; and a filler passage associated with said storage unit for supplying hydrogen to said dehydrogenated storage material in said storage unit.

196. (withdrawn) The power device according to claim 195 wherein said dehydrogenated state comprises an oxide.

197. (withdrawn) The power device according to claim 195 wherein a hydrogen supply source delivers hydrogen at a temperature and pressure above ambient conditions to said storage material via said filler passage.

198. (withdrawn) The power device according to claim 195 wherein when said hydrogen storage material is dehydrogenated, said hydrogen provided to the power device regenerates said storage material from said dehydrogenated state to a regenerated hydrogenated state.

199. (withdrawn) The power device according to claim 195 wherein said storage unit is capable of being removed from the power device to regenerate said storage material from a dehydrogenated state to a regenerated hydrogenated state.



**EVIDENCE APPENDIX**

**Evidence Pursuant to §§ 1.130, 1.131, or 1.132 or Entered by or Relied Upon by the Examiner being Submitted in the Appeal of Application Serial No. 10/787,292.**

NONE

**RELATED PROCEEDINGS APPENDIX**

**Proceedings Related to the Appeal of Application Serial No. 10/787,292.**

NONE